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# Ergodicity in Geomorphology

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**Introduction**

Several methods have been offered to explain the uneven change patterns in the form of developmental investigations as well as studies of geomorphologic processes and systematic literature probes. One of these methods entails the creation of a mathematical model based on analytic extrapolations and numerical simulations, while another is modeling physical landscape changes, using reality display hard wares on a small scale (Massly and Zimpfer, 1976). A third approach is based on the assumption that creating the revolutionary patterns of a geomorphic landscape can be reconstructed by analyzing the phenomenal procedure present on the site, and therefore the difficulties of time could be eliminated by developmental changes. Accordingly, it is believed that if one landscape elapses its revolution creation in six stages, it is not necessary to observe and record the analysis from the start to the end, but in every stage of creation, the index form in the change scene is created as a prevailing phenomenon in which such forms are not destroyed in successive stages and few remain in the landscape. Now, if in the final stage of geomorphic landscape we witness several forms, which do not create the prevailing form but which exist in the scene, then each of the remaining forms can be separated and shown.

By default, we can consider any form of the model as a logical representative of a period of time in the development hierarchy, and hence based on the variety of forms that we have seen, conclusions can be drawn about the changes occurred over time. Statistically speaking, we can call this data sampling method “Ergodic”, as spatial alternative collections of time.

“Ergo” in the Greek language means work or energy and “hodos” means way (Pain, 1985). In simple words, Ergodicity in Geomorphology denotes a historically revolutionary change model of phenomena so that these changes could be classified into different stages. The most important feature of this classification is based on the same average change rate during each stage of development.

The purpose of the present study, taken from a theoretical project at Isfahan University, is to describe the ergodicity concept in geomorphology using a watershed basin created by a miniature model in a natural space (crack areas of Meybod Plain), to evaluate its changes influenced by artificial rain, and to describe the case of ergo concept which has not been widely perused in geomorphology

**Research Methodology**

The data analyzed in this research are related to the changes in a single miniature basin that is obtained by an artificial rainfall in four separate stages. Initially, measures were taken to evaluate the desired location in crack areas of Meybod, Yazd. A miniature basin in completely natural conditions and without any artificial manipulation situated in 25 km north Yazd with 500m distance from main road with an extent of 10 m2 was selected. After marking and preparing the basin to obtain the base map, the researchers took vertical images of the miniature basin, and initial height data were obtained via installed index, determining the base line level and measuring the height of each indicator installed with the base index level. Despite the continuous rainfall, there was no precipitation outside the basin. Continuing the operation in the next day showed that a special state called “Steady State” was obtained which established the stability. Afterwards, the driven data had to be extended so that instead of four forms of basins an interface could be achieved.

In this stage, the continuous mode of change in the basin has been measured, using GRD files and their processing in Wechsler Software. With the extended data in this software, fifty frames of the basin change patterns were obtained and image and paired analysis of the fifty frames driven were possible in DiGem Software with a statistical analysis framework. The paired analysis on the basis of statistical indicators enabled us to calculate the average change in each stage, the separate transformation stage and the time phase.

**Discussion and Results**

Ergodicity in geomorphology means models of historical revolutionary changes of a phenomenon so that these changes can be classified into different stages. The notion of the separate stage is based on average rate of change in each phase. In other words, levels which have an equal moderate variation are considered as a phase. On the other hand, the change development process of each geomorphologic phenomenon can have an indicator stage.

By implementing the first stage of rainfall, assessment has been done to the changes occurred at the rainfall scene, and the subsequent rainfall phase is continued. This evaluation is carried on up to the last stage. In the fifth stage of rainfall, however, the basin outlet reached zero although the long-run rainfall did not show any changes in the outlet. Next day, this operation was repeated and the same results were obtained. Such cases represent the achievement of a stable system, i.e. a desired change to zero. The total rainfall conducted on the basin from the start till the end of the modeling was 206.5 min, and Debi of rainfall was 0.569 Li/s.

It is important to point out that severe rainfall with constant Debi till the last stage was done. After obtaining the digital data of the basin in four rainfall stages, these figures should be changed into intermediate figures so that the evolution of the basin in the conditions of these four stages can be reconstructed. This was done using the Voxler Program, and the obtained numbers were converted to images so as to show all continuous changes between the first and the fourth stage

The Voxler Software can show all the changes in the stages in the form of continuous images. After achieving the preliminary imagery analysis of the prepared files in the Voxler Software, the researchers converted it to Digem Software Program. Due to the high capability of this software, images of the basin changes were prepared in 50 separate frames (figure 4). This enables us to study the 50 achieved phases rather than to evaluate the phase that has equivalent average changes and the ratio of separate phase change that indicates the proceeded ergodic stages.

**Conclusion**

Although various methods exist, including mathematical models based on extrapolation, reconstruction model and analysis of forms present on scene, geo-allometric model and physical modeling of landscape changes using reality display hardware in a smaller scale is highly significant to explain the development, the accuracy of the simulation miniature method in development stages, and changes of phases in a watershed basin. As the research analysis demonstrated, three distinct phases of change development in relation to the miniature watershed model are extractable, and similar results are shown with the quantitative method as well as the qualitative method. Phase 1 consists of 1-9 stages (figure 4) and is recognized as the first spatial phase in which the structural equilibrium will begin to change. The second phase is 10-24 where in-equilibrium is intensive, whereas the third phase consists of 25-50 stages, repeated movements with negative feedback that start towards other equilibriums. Of course, each stage known as a macro phase is divided into several micro phases, indicating the position, intensity and magnitude of the change index. On the basis of what was shown in figure 5 and 6, it is clear that the micro phase based on the macro phase is distinguishable.

According to figure 2, the height changes of the four frames found in the basin make clear that equilibrium, the mechanism of corrosion and its repeated rehabilitation in the basin are the function of operational forces. Regarding the prevailing process in miniature model, rainfall can also be considered for other modeling processes. In this way, different ergodic process models can be compared. For the purpose of modeling the changes, the softwares used in this research; namely, Didger, Voxler and Surfer are recommended. Of course, stating engineering obligations and limitations in applying these softwares are very important; this is, however, beyond the scope of the present study. Another important finding in this study is the true function of the standard deviation of digital height data to determine the phase of ergodic changes, not being mentioned in other similar researches. However, with extensive experiments and especially using tectonic in the miniature model, new illuminating findings will certainly be achieved that will guide related studies regarding the substitution of time and space.

On the other hand, the researchers' access to efficient softwares in the field of extended and digital reconstruction period could help us to detect the non-registered processes. Therefore, the complexity of Ergodicity discussion neglected in Geomorphology can be explained on the strength of accurate digital and statistical documents. Substituting categories of space with time is one of the main goals of Ergo, which is, indeed, possible and practical. As seen, 8 phases of change in the changes of miniature basin were detected, and even on the strength of different rate of standard deviation, steps with visual capabilities, which could not be distinguished accurately, are feasible now.

**Keywords:** Ergodic, model, analog, progressive changes, landscape changes ,theoric geomorphology

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